CAN HST MEASURE THE MASS OF THE ISOLATED NEUTRON STAR RX J185635-3754 ?

Bohdan Paczyński

E-mail: bp@astro.princeton.edu

Princeton University Observatory, 124 Peyton Hall, Princeton, NJ 08544-1001, USA

ABSTRACT

In June 2003 the isolated neutron star RX J185635-3754 will pass within $\sim 0.3''$ of a 26.5 mag star, changing its position by about 0.6 mas. The displacement, caused by gravitational lensing, will be proportional to the neutron star mass. The total event duration will be approximately 1 year.

- - - - - - - -

The possibility of measuring stellar masses using astrometric effects of gravitational lensing were discussed by Hog et al. (1995), Miyamoto & Yoshii (1995), Paczyński (1995, 1996, 1998), Miralda-Escudé (1996), and Boden et al. (1997). The recent detection of a fast moving nearby neutron star RX J185635-3754 (Walter 2001) offers an opportunity to implement this method in practice. RX J185635-3754 is at the distance of 61 pc, and in June 2003 it will pass within $\sim 0.3'' = 300$ mas of the star marked as # 115 in Fig. 1 of Walter (2001). The star #115 has magnitude $M_{F606W} = 26.5$, the neutron star has a parallax of 16 mas, and a proper motion of $\dot{\varphi} = 332$ mas/year.

While the neutron star will be passing within $\Delta\varphi \approx 300$ mas of our line of sight towards the star #115, the position of the latter will be displaced by up to

$$\delta\varphi = \frac{\varphi_{\mathrm{E}}^2}{\Delta\varphi}, \tag{1}$$

where φ_E is the neutron star's Einstein ring radius (cf. Fig. 1 and eq. 4 of Paczyński 1996).

Einstein ring radius is given with the eq. (1) of Paczyński (1996):

$$\varphi_{\mathrm{E}} = \left(\frac{4\mathrm{GM}}{\mathrm{c^2 d_\pi}}\right)^{1/2} \tag{2}$$

where $1/\mathrm{d_\pi}$ is the parallax distance to the lens (RX J185635-3754) as measured with respect to the more distant source (star #115):

$$\frac{1}{\mathrm{d_\pi}} \equiv \frac{1}{\mathrm{D_d}} - \frac{1}{\mathrm{D_s}}. \tag{3}$$

Adopting $\mathrm{D_d} = 61$ pc, $\mathrm{D_s}/\mathrm{D_d} \gg 1$, and $\mathrm{M} \approx 1.4\ \mathrm{M_\odot}$ we obtain

$$\varphi_{\mathrm{E}} \approx 14\ \mathrm{mas}. \tag{4}$$

By coincidence this Einstein ring radius is almost the same as the parallax of the neutron star. The time scale for the lensing event will be

$$\Delta\mathrm{t} \equiv \frac{\Delta\varphi}{\dot{\varphi}} \approx 1\ \text{year}. \tag{5}$$

The maximum displacement of the position of star #115 due to lensing by the neutron star will be approximately (cf. eq. 1):

$$\delta\varphi \approx \frac{(14\ \mathrm{mas})^2}{300\ \mathrm{mas}} \approx 0.6\ \mathrm{mas}. \tag{6}$$

This is a very small displacement, but it may be measurable with the new Advanced Camera for Surveys (ACS - http://www.stsci.edu/cgi-bin/acs), which is to be mounted on the Hubble Space Telescope before the end of 2001.

The angles φ_E, $\Delta\varphi$, and $\delta\varphi$ as given above, are only estimates. However, when all these angles are measured the mass of the neutron star follows from the combination of eqs. (1-3):

$$\frac{M}{M_\odot} = \frac{c^2 d_\pi}{4G} \, \delta\varphi \, \Delta\varphi = 2.25 \, \frac{d_\pi}{61 \text{ pc}} \, \frac{\delta\varphi}{1 \text{ mas}} \, \frac{\Delta\varphi}{300 \text{ mas}}. \tag{7}$$

There are many precedents for the HST based determination of a parallax with an accuracy of ~ 0.1 mas (e.g. McArthur et al. 2001), but those were done for stars much brighter than either star #115 or RX J185635-3754. The parallax of the faint neutron star was measured with an accuracy of ~ 2 mas with the Wide Field Planetary Camera 2 (Walter, 2001). The HST astrometry should be more accurate with the Advanced Camera for Surveys, which will become operational by early 2002, with plenty of time to make the preparations for the lensing event of June 2003. Such a measurement may provide a novel check on the estimates made by Pons et al. (2001)

This paper is posted on astro-ph only, and it will not be submitted to any paper journal. The author welcomes all critical comments by the readers, in particular about missing references. It is a pleasure to acknowledge the support from the NSF grant AST-9820314.

REFERENCES

Boden, A. F., Shao, M., & Van Buren, D. 1997, ApJ, 502, 538

Hog, E., Novikov, I. D., & Polnarev, A. G. 1995, A&A, 294, 287

McArthur, B. E. et al. 2001, astro-ph/0107026

Miralda-Escudé, J. 1996, astro-ph/9605138 = ApJ, 470, L113

Miyamoto, M., & Yoshii, Y, 1995, AJ, 110, 1427

Paczyński, B. 1995, astro-ph/9504099 = AcA, 45, 345

Paczyński, B. 1996, astro-ph/9606060 = AcA, 46, 291

Paczyński, B. 1998, astro-ph/9708155 = ApJ, 494, L23

Pons, J. A. et al. 2001, astro-ph/0107404

Walter, F. M. 2001, astro-ph/0009031 = ApJ, 549, 433